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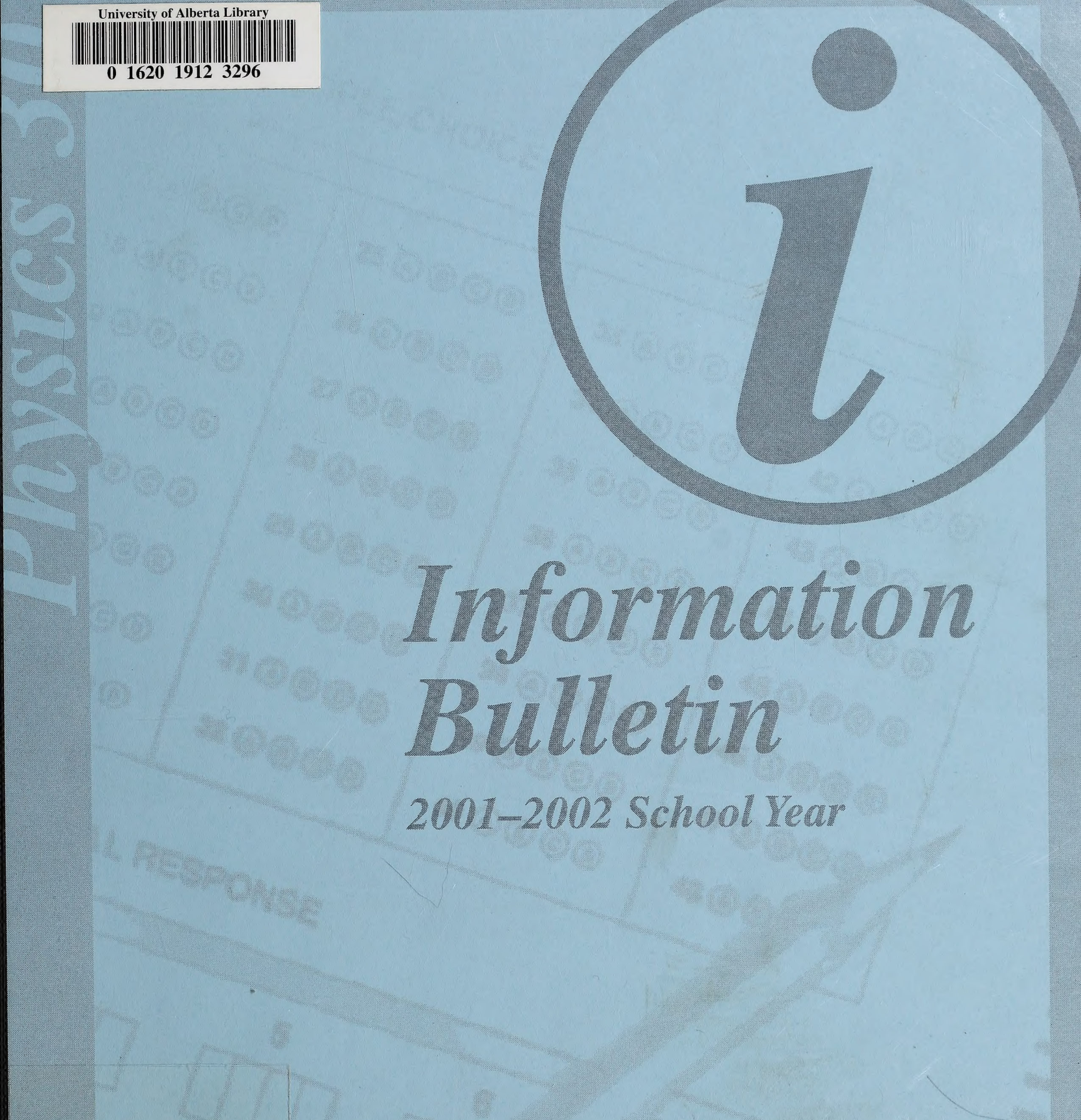

Physics 3

Information Bulletin

2001–2002 School Year

Diploma Examinations Program

Alberta
Learning

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Contents

Page 1 Objectives of the Course

Page 1 Performance Expectations

Page 2 Examination Specifications

Page 4 Examination Design

Page 6 Assessment of STS Connections

Page 7 Assessment of Communication Skills

Page 7 Reminders and Explanations

Page 15 Numerical-Response Questions

Page 16 Written-Response Questions

NEW **Sample Open-Response Question, Solution, Scoring Guide, Students' Responses, and Rationales**

Sample Analytic Question, Solution, Scoring Guide, Students' Responses, and Rationales

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Objectives of the Course

Physics 30 is intended to further students' understanding and application of fundamental physics concepts and skills. The focus of the course is on understanding the physics principles behind the natural events that students experience and the technology that they use in their daily lives. The course encourages enthusiasm for the scientific enterprise and develops positive attitudes about physics as an interesting human activity with personal meaning. It develops the knowledge, skills, and attitudes to help students become capable of and committed to setting goals, making informed choices, and acting in ways that will improve their own lives and life in their communities.

To develop the required knowledge, skills, and attitudes in Physics 30, it is necessary that students have successfully completed Science 10 and Physics 20.

Curriculum Standards

Provincial curriculum standards help to communicate how well students need to perform in order to be judged as having achieved the objectives specified in the *Physics 20–30 Program of Studies, Interim 1995*. The specific statements of standards are written primarily to apprise Physics 30 teachers of the extent to which students must know the Physics 30 content and be able to demonstrate the required skills in order to pass the examination.

Performance Expectations

Acceptable Standard

Students who achieve the *acceptable standard* in Physics 30 will receive a final course mark of 50% or higher. Students achieving the *acceptable standard* have gained new skills and knowledge in physics but may encounter difficulties if they choose to enroll in post-secondary physics courses. These students are able to state and solve problems that can be related quickly to an equation on the data sheet. Their laboratory skills are limited to following explicit directions and to using laboratory data to verify known physics information. These students are capable of defining and calculating quantities such as one-dimensional momentum; kinetic and potential energies; electric force and the force due to gravity; current, potential difference, and resistance in simple series and parallel circuits; variables in the relationship between the primary and secondary coils of a transformer; speed, wavelength, and frequency of electromagnetic waves; charge-to-mass ratios; and the photoelectric work function. They tend to use item-specific methods in their problem solving and rarely apply the major generalizations of physics such as conservation laws or balanced and unbalanced forces to their solutions. When explaining the connections between science, technology, and society, these students tend to use examples provided from textbooks. These students have difficulty connecting physics to real-life scenarios beyond the classroom.

Standard of Excellence

Students who achieve the *standard of excellence* in Physics 30 receive a final course mark of 80% or higher. They have demonstrated their ability and interest in both mathematics and physics and feel confident about their scientific abilities. These students should encounter little difficulty in post-secondary physics programs and should be encouraged to pursue careers in which they will utilize their talents in physics. Students who achieve the *standard of excellence* show flexibility and creativity when solving problems, and minor changes in problem format do not cause them major difficulties. In the laboratory, students who achieve the *standard of excellence* can deal with data that are less than perfect or with instructions that are incomplete. These students are capable of defining and calculating quantities such as two-dimensional momentum, current and voltage using Kirchhoff's rules, resistance in series and parallel circuits, the motion of an electric charge in a magnetic field, and variables in the Balmer equation. They seek general methods to solve problems and are not afraid to use conservation laws. They transfer knowledge from one area of physics to another and can express their answers in clear and concise terms. In addition, these students can connect their understanding of physics to real-world situations that include technological applications and implications beyond the classroom setting.

Examination Specifications

Each Physics 30 Diploma Examination is constructed as closely as possible to the following specifications. Adjustments in the emphasis may be necessary because the examination includes written-response questions and/or machine-scored questions that cover more than one general learner expectation. Questions on the diploma examination will require students to demonstrate knowledge of physics concepts and to apply skills in a context that supports making STS connections.

The design supports the integration of all Physics 30 general learner expectations (GLEs) as outlined in the *Physics 20–30 Program of Studies, Interim 1995*. As a result, the examination is not necessarily arranged sequentially by units but instead is built around scenarios or contexts that support STS connections. Therefore, a set of questions may assess students' ability to integrate several general learner expectations (GLEs). All questions will measure achievement of scientific knowledge; some will also measure achievement of scientific process and communication skills and/or STS connections.

The 2001–2002 Physics 30 diploma examinations are constructed to place the following approximate emphases on the Physics 30 course general learner expectations.

Knowledge	***Emphasis***
The student can	
• compare and contrast scalar and vector quantities and fields; apply the concept of field to quantitatively explain, in terms of their source, direction, and intensity, the gravitational, electrical, and magnetic effects on objects and systems	10–20%
• describe quantitatively, analyze, and predict the behaviour and physical interactions of objects that may be in gravitational, electric, and/or magnetic fields, using the principles of kinematics, dynamics, conservation of energy, momentum, and electric charge, in addition to electrostatics and electromagnetism; apply these principles to atomic theory and other applications	35–45%
• explain quantitatively, analyze, and predict the motor/generator effect; describe quantitatively, analyze, and predict the functioning of simple resistive direct current circuits, using Ohm's law and Kirchhoff's rules; explain the design, function, and technological applications of simple electric motors, generators, meters, transformers, and other simple electromagnetic devices	10–20%
• explain quantitatively the characteristics and behaviours of electromagnetic waves, and algebraically solve problems using the relationship among speed, wavelength, frequency, and energy, and apply these principles with conservation laws to the atomic theory and other applications	25–35%

Scientific Process and Communication Skills	***Emphasis***
The student can	20–40%

- design, interpret, explain, analyze, and evaluate investigations
- organize data into tables, graphs, and diagrams, and predict relationships
- interpret, explain, analyze, and evaluate data to infer relationships
- use appropriate scientific terminology and mathematical language to communicate and explain scientific concepts

Science, Technology, and Society Connections (STS)	***Emphasis***
The student can	40–60%

- apply cause-and-effect reasoning to formulate relationships in which scientific evidence shapes or refutes a theory, and explain the limitations of science and technology in answering all questions and solving all problems
- describe and evaluate the design and function of technological solutions to theoretical and practical problems using scientific principles and theories, and relate the ways in which science and technology advance one another
- evaluate from a variety of perspectives how science and technology are influenced and supported by society, and assess the ability of society to interact responsibly with the environment
- apply the skills and knowledge acquired in Physics 30 to everyday life and to related and new concepts in post-secondary studies

Examination Design

The design of the 2001–2002 Physics 30 diploma examinations is as follows:

Question Format	*Number of Questions*	*Percent Emphasis*
Multiple Choice	37	53
Numerical Response	12	17
Written Response	2	30

The machine-scored portion of each examination contains both multiple-choice and numerical-response questions, some of which may be linked.

Answers for multiple-choice questions are recorded in the first section of the machine-scored answer sheet. Answers for numerical-response questions are recorded in the second section on the same side of the same machine-scored answer sheet. Answers to the written-response questions are written in the examination booklet.

Multiple-choice questions are of two types: *discrete* and *context-dependent*. A discrete question stands on its own without any additional directions or information. It may take the form of a question or an incomplete statement. A context-dependent question provides information separate from the question stem. Many of the multiple-choice questions are *context-dependent*. A particular context may be used for more than one multiple-choice question as well as for one or more numerical-response questions.

Numerical-response questions are of three types: calculation of numerical values; selection of numbered events, structures, or functions from a diagram/list; and determination of a sequence of events.

The **written-response** portion of the Physics 30 Diploma Examination contains two questions: an open-response question that is scored using a holistic scoring guide, and an analytic question that is scored using an anaholistic scoring guide.

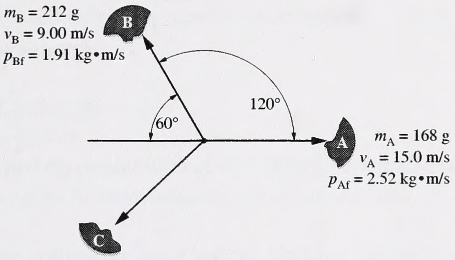
The Physics 30 Diploma Examination uses some linked questions in the multiple-choice and numerical-response section. A numerical answer from one question may be necessary to complete the calculations in the next question. If students answer the first question incorrectly but use that answer correctly to answer the second question, they will receive full marks for the second question. These variations in answers are accommodated by the program designed for electronic scoring.

Linked Questions

An illustration of linked questions taken from the January 1999 Physics 30 Diploma Examination is shown below.

Use the following information to answer the next two questions.

A glass ornament of mass 575 g sitting on a table is subjected to a resonant frequency of 440 Hz. The ornament breaks into three pieces that travel horizontally across the frictionless tabletop. Fragment **A** has a mass of 168 g and fragment **B** has a mass of 212 g.



10. The magnitude of the momentum of the third piece of glass, fragment **C**, is

A. 5.19 kg•m/s

B. 3.85 kg•m/s

***C.** 2.28 kg•m/s

D. 0.610 kg•m/s

*Use your recorded answer from **Multiple Choice 10** to answer **Numerical Response 4**.**

Numerical Response

4. The speed of the third fragment of glass, expressed in scientific notation, is $b \times 10^{w}$ m/s. The value of b is __________.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

***You can receive marks for this question even if the previous question was answered incorrectly.**

The correct answer to multiple-choice 10 is 2.28 kg•m/s. The mass of the third fragment is $m_c = 575\text{ g} - (212\text{ g} + 168\text{ g}) = 195\text{ g} = 0.195\text{ kg}$. Since $v = \frac{p}{m}$, $v = \frac{2.28\text{ kg}\cdot\text{m/s}}{0.195\text{kg}} = 11.7\text{ m/s}$. The speed of the third fragment, expressed in scientific notation, is 1.17×10^1 m/s, so the value of ***b*** is 1.17. This value is marked as being correct regardless of the answer to multiple-choice question 10. The table below shows the responses to multiple-choice question 10 and the corresponding correct responses to numerical-response question 4.

If response to MC 10 is	**then response to NR 4 is**
A	2.66
B	1.97
C	1.17
D	3.13

Assessment of STS Connections

Examination questions measure the students' understanding of concepts from the *Physics 20–30 Program of Studies, Interim 1995*. Some questions also measure the students' use of the skills and thinking processes associated with scientific inquiry. In addition, questions have been designed to measure students' understanding of the interrelationship between science and technology and among science, technology, and society.

Industries, businesses, and post-secondary institutions in Alberta have been helpful in providing real-life contexts for STS questions, as well as in making connections between real life and the curriculum. The contributions of these institutions have enhanced the quality of the diploma examination program in Alberta.

The development of test items, from the writing stage until they appear on an examination, may take a couple of years. For the 2001 Physics 30 Diploma Examination, we would like to recognize the contributions of the following institutions:

University of Alberta, Department of Physics
University of Alberta, Department of Secondary Education
University of Calgary, Department of Physics and Astronomy
TransAlta

Assessment of Communication Skills

Communication skills are assessed most directly in the marker-scored questions. For the open-response question, the descriptions used in the scoring guide include criteria for assessing communication skills along with criteria for assessing science content. The scoring criteria for the open-response question can be found on page 18.

The term *communication skills* refers to those processes by which information is expressed using appropriate conventions. These conventions include:

- words, sentences, paragraphs
- graphs, diagrams, tables
- mathematical formulas, mathematical and chemical equations
- significant digits, units of measurement, unit conversion

Conventions that are considered appropriate for a particular response are subject- and question-specific.

Reminders and Explanations

Field-test results for the 2000–2001 school year indicate that students continue to improve in their ability to organize their written work and to address all aspects of the written-response questions. The reminders that follow are based on concerns that have been expressed by field-test teachers and markers.

Constants

Students should use constants provided on the data sheet and recorded to three significant digits, rather than constants stored in calculators. This is important in order to obtain correct numerical-response answers.

Nuclear Equations

The curriculum specifies that students should be able to write nuclear equations for alpha and beta decay. Often, the decay process results in the release of other particles such as neutrinos or positrons. Students are not expected to know the characteristics of these particles. However, students may be asked to use information given to them regarding these particles in order to determine the solution to a question.

Common Graphing Errors

Errors students commonly make when graphing and curve straightening include:

- placing the manipulated and responding variables on the wrong axes
- drawing a linear graph through non-linear data points
- forgetting to include units or powers of 10 when calculating slope or using other averaging techniques
- forgetting to perform algebraic manipulation on units and powers of 10 when doing curve straightening

Graphing Procedures

Some general guidelines for graphing scientific data follow.

- The manipulated variable should be plotted on the horizontal axis, and the responding variable should be plotted on the vertical axis.

- The scale for each axis should be set so that it evenly distributes the measured data using as much of the graph as possible. Scales should be easy to read and evenly divided. All axes must be labelled with the variable used and with complete units, including any power of 10.

- The graph should have a clear title. This is usually stated as "Responding versus Manipulated" variable, with a further descriptor to help identify the data.

- Each data point should be plotted. A small circle may be drawn around each plotted point to indicate that it is a data point. Best-fit lines or curves may not include points caused by experimental error. Best-fit lines or curves do not necessarily include the origin.

Graphing with a Graphing Calculator

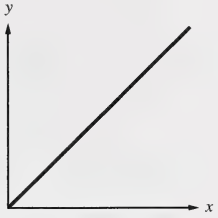
The answer provided by students who choose to use a graphing calculator to plot the data and draw the best-fit line should include:

- a title
- a statement or label of the variable plotted on the *x*-axis including units and power of 10
- a statement or label of the variable plotted on the *y*-axis including units and power of 10
- a statement of the range of both axes by recording minimum and maximum *x* and *y* values
- a reasonable sketch of the calculator display

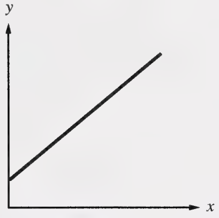
Graphing Recognition

Students seem to experience difficulty in connecting the shape of a graph with the corresponding mathematical equation. Students should recognize the following basic relationships.

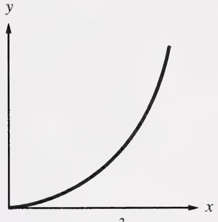
Direct Variation



$y = mx$

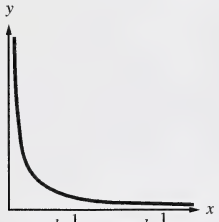


$y = mx + b$



$y = kx^2$

Inverse Variation



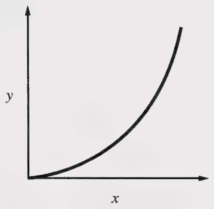
$y = k\frac{1}{x}$ or $y = k\frac{1}{x^2}$

Suggestions for Curve Straightening

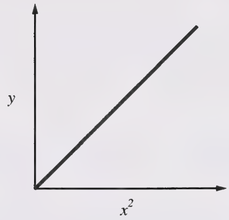
One purpose of graphing data is to allow students to see the relationship between variables. Curve straightening is used to change a curved graph into a linear one. A linear graph provides easy access to information on slope and intercepts. This method of data analysis allows the student to connect experimental results to general physics principles. Some suggestions for curve straightening follow.

- Identify the manipulated and responding variables.
- Plot the data. Identify the shape and relationship.
- Algebraically manipulate one of the variables to produce a linear graph. Include units and powers of 10 during the data manipulation.

  Example: The data from an experiment is graphed and the following graph results.



The shape, a parabola, implies a squared relationship between the variables. Data manipulation would involve taking the *x*-values (including powers of 10) from the data and squaring them. Plotting the revised data gives a linear graph, as shown below.



Note: Using formulas from the data sheet and solving for the responding variable may help to predict the shape of the initial graph and direct the data manipulation.

Averaging Techniques

Students should be made aware that finding slope is the most suitable averaging procedure we have. Therefore, when they are required to use an averaging procedure to analyze data, slope should be their first choice.

If slope is not used as an averaging technique, students should then use the average of the desired values, (the weighted mean). They should not average the manipulated and responding variables. Care must be taken when using these averaging methods because the origin or another non-permissible value may be given as data.

Finding Slope From a Graph

Generally, students understand that slope is defined as the rise/run. Some general guidelines for finding slope follow.

- Always use points on the line that can be read easily.
- Data points should not be used in a slope calculation.
- The points selected should result in a large Δx and Δy so as to maximize the accuracy of the slope calculation.
- The origin should not be assumed to be a suitable point.
- Units and powers of 10 given on the axes should be included in the calculation and final answer.
- Significant digits for the slope are determined by the precision of the observations recorded in the data table.

Finding Slope Using a Graphing Calculator

Students may enter data points, including powers of 10, into a table on their calculators and then use a linear regression program to determine the slope of the best-fit line.

The complete communication of this method should include:

- a statement of where the data are stored in the calculator
- a statement of how the variables are being compared (manipulated vs. responding)
- the value of the slope with appropriate significant digits, powers of 10, and units

The following example is taken from the January 1999 Physics 30 Diploma Examination to illustrate each of the averaging techniques.

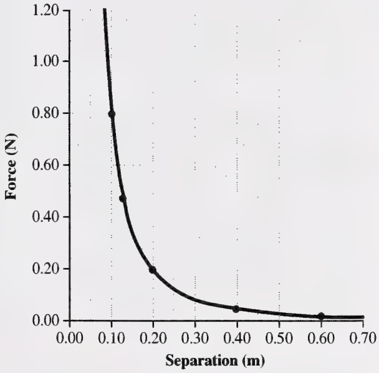
Examples of Suitable Averaging Procedures

Use the following information to answer the next question.

A student performed an experiment that verified Coulomb's Law of Electrostatics by measuring the repulsion between two charged spheres, A and B, as a function of the separation of the spheres. The spheres were identical in size and mass. The measurements are shown in the table of values and plotted on the graph below.

Separation (m)	Force (N)
0.10	0.790
0.13	0.480
0.20	0.200
0.40	0.050
0.60	0.022

Force of Repulsion as a Function of the Separation



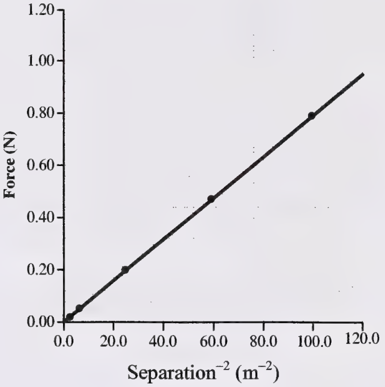
- Show that the results verify Coulomb's Law by manipulating the data and providing a new table of values that, when plotted, will produce a straight-line graph.

New Table of Values	
$\frac{1}{\text{Separation}^2}$ (m^{-2})	Force (N)
100	0.790
59	0.480
25	0.200
6.3	0.050
2.8	0.022

- Plot the new data with the responding variable on the vertical axis.

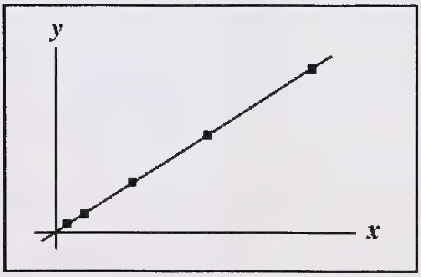
Method 1
Graphing on Paper

Force of Repulsion as a Function of the Inverse of the Separation Squared



Method 2
Graphing with a Graphing Calculator

Force of Repulsion as a Function of the Inverse of the Separation Squared



$x_{min} = -7$

$x_{max} = 110$

$y_{min} = -0.1$

$y_{max} = 0.9$

$\frac{1}{r^2}$ in m^{-2} plotted on x-axis

F in N plotted on y-axis

- Calculate the slope of your graph.

Method 1
Finding the Slope Using the Best Fit Line

$$\begin{aligned} \text{slope} &= \text{rise/run} \\ &= \frac{0.60\ \text{N} - 0.16\ \text{N}}{(76 - 20)\ \text{m}^{-2}} \\ &= 7.86 \times 10^{-3}\ \text{N•m}^2 \end{aligned}$$

slope $= 7.9 \times 10^{-3}$ N•m^2 **or** consistent with the graph

Method 2
Finding the Slope Using a Graphing Calculator

$$\text{L1} = \frac{1}{r^2}\,(m^{-2})$$

$$\text{L2} = F(N)$$

Use the linear regression on the calculator: $(ax + b)$ L1, L2, Y

The slope is 7.9×10^{-3} N•m^2

Note: The definition of L1 and L2 and the order they are used in the linear regression must be consistent.

- Using the slope value, or another suitable averaging technique, determine the charge on sphere **B** if the charge on sphere **A** is 3.08×10^{-7} C.

Method 1
Slope

$$F_e = \frac{kq_Aq_B}{r^2}$$

$$\begin{aligned} q_B &= \frac{F_e r^2}{kq_A} = \frac{\text{slope}}{kq_A} \\ &= \frac{7.86 \times 10^{-3}\ \text{N•m}^2}{(8.99 \times 10^9\ \frac{\text{N•m}^2}{\text{C}^2})(3.08 \times 10^{-7}\text{C})} \end{aligned}$$

$q_B = 2.8 \times 10^{-6}$ C or consistent with slope

Method 2
Weighted Average

$$F_e = \frac{kq_Aq_B}{r^2} \qquad q_B = \frac{Fr^2}{kq_A}$$

$$q_B = \frac{(0.790\ \text{N})(0.10\ \text{m})^2}{(8.99 \times 10^9\ \frac{\text{N•m}^2}{\text{C}^2})(3.08 \times 10^{-7}\text{C})}$$

$$
\begin{aligned}
q_{B_1} &= 2.853 \times 10^{-6}\ \text{C}\\
q_{B_2} &= 2.930 \times 10^{-6}\ \text{C}\\
q_{B_3} &= 2.889 \times 10^{-6}\ \text{C}\\
q_{B_4} &= 2.889 \times 10^{-6}\ \text{C}\\
q_{B_5} &= 2.860 \times 10^{-6}\ \text{C}\\
q_{B(AVE)} &= \frac{q_{B_1} + q_{B_2} + q_{B_3} + q_{B_4} + q_{B_5}}{5}\\
q_{B(AVE)} &= 2.884 \times 10^{-6}\ \text{C}\\
q_{B(AVE)} &= 2.88 \times 10^{-6}\ \text{C}
\end{aligned}
$$

Unsuitable Averaging Technique

The following method yields an unreasonable value for the charge on sphere **A**. This method is considered unacceptable.

$$
\begin{aligned}
\text{Average Separation} &= \frac{r_1 + r_2 + r_3 + r_4 + r_5}{5}\\
&= \frac{0.10\ \text{m} + 0.13\ \text{m} + 0.20\ \text{m} + 0.40\ \text{m} + 0.60\ \text{m}}{5}\\
&= 0.286\ \text{m}
\end{aligned}
$$

$$
\begin{aligned}
\text{Average Force} &= \frac{F_1 + F_2 + F_3 + F_4 + F_5}{5}\\
&= \frac{0.790\ \text{N} + 0.480\ \text{N} + 0.200\ \text{N} + 0.050\ \text{N} + 0.022\ \text{N}}{5}\\
&= 0.308\ \text{N}
\end{aligned}
$$

$$
\begin{aligned}
F_{AVE} &= \frac{k q_{BAVE}\, q_A}{r_{AVE}^{\ 2}}\\
q_{B(AVE)} &= \frac{F_{AVE}\, r_{AVE}^{\ 2}}{k q_A}\\
q_{B(AVE)} &= \frac{(0.308\ \text{N})(0.286\ \text{m})^2}{(8.99\times10^{9}\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2})(3.08\times10^{-6}\ \text{C})}\\
q_{B(AVE)} &= 9.10 \times 10^{-7}\ \text{C}
\end{aligned}
$$

Numerical-Response Questions

Three examples of numerical-response questions are shown on this page. Teachers should ensure that their students become familiar and comfortable with these formats before students write the Physics 30 Diploma Examination.

Numerical Response

1. During the Second World War, to help aircraft avoid radar detection, metal-foil strips cut to one-half of the radar's wavelength were dropped from the aircraft. These strips reduced the effectiveness of the radar. The 30.2 cm metal-foil strips were designed for a radar frequency, expressed in scientific notation, of $\boldsymbol{b} \times 10^{w}$ Hz. The value of $\boldsymbol{b}$ is ________.
(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

Answer: $\boxed{4}\boxed{.}\boxed{9}\boxed{7}$

Use the following information to answer the next question.

Types of EMR

1 Blue light
2 Gamma radiation
3 Radio waves
4 Ultraviolet radiation

Numerical Response

2. When the types of EMR above are listed in order from the highest energy to the lowest energy, the order is ________, ________ ,________ , and ________
highest energy lowest energy
(Record your **four-digit answer** in the numerical-response section on the answer sheet.)

Answer: $\boxed{3}\boxed{1}\boxed{4}\boxed{2}$

Numerical Response

3. An X-ray tube operates with a potential difference of 4.5×10^{4} V. The minimum wavelength of X-rays being produced, expressed in scientific notation, is $\boldsymbol{a}.\boldsymbol{b} \times 10^{-\boldsymbol{cd}}$ m. The values of $\boldsymbol{a}$, $\boldsymbol{b}$, $\boldsymbol{c}$, and $\boldsymbol{d}$ are ___, ___, ___, and ___.
(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

Answer: $\boxed{2}\boxed{8}\boxed{1}\boxed{1}$

Written-Response Questions

Each Physics 30 Diploma Examination has two written-response questions. Written-response questions are each weighted 15% of the total examination. The written-response component is worth 30% of the total examination. The machine-scored component is worth 70% of the total examination.

The first written-response question is an open-response question. Each student's answer to the open-response question is scored independently by two markers using the holistic scoring guide. The holistic scoring guide describes the characteristics of the student's answer that correspond to one of six values (0, 1, 2, 3, 4, or 5). The descriptor for each level addresses the level of understanding demonstrated by the student, the completeness of the response, and the level to which the student communicates his or her understanding of the physics principles involved in solving the problem. Each scoring guide identifies the major concepts that a complete answer must address.

For an example of an open-response question, scoring guide, and samples of students' work see pages 17 to 24.

The second written-response question is an analytic question. Each student's answer is scored independently by two markers using an anaholistic scoring guide. The anaholistic scoring guide describes the characteristics of the student's answer that correspond to one of six values (0, 1, 2, 3, 4, or 5). The descriptor for each level addresses the level of understanding demonstrated by the student, the completeness of the response, and the level to which the student communicates his or her understanding of the physics principles involved in solving the problem. Each scoring guide identifies the four major concepts that a complete answer must address.

For a sample of an analytic question, a sample anaholistic scoring guide, and samples of students' work, see pages 25 to 30.

For both written-response questions, the scores are obtained by two independent markers. If these scores vary by 2 or more, the scores are classified as *discrepant*. Responses that have *discrepant* scores are read by a third marker. The third marker must assign a score that is equal to one of the scores of the first two markers or that is between these scores.

A summary of the calculation for a discrepant paper follows.

Content: Marker 1 assigned a score of 1 out of 5 marks
Marker 2 assigned a score of 3 out of 5 marks
Marker 3 must assign a score of 1, 2, or 3.

Sample Open-Response Question, Solution, Scoring Guide, Students' Responses, and Rationales

Written-Response Question 1, June 1998

Use the following information to answer the next question.

A site contains soil that is radioactive. The soil may be emitting one or more of alpha particles, beta particles, or gamma rays. As the physics expert for the clean-up crew, you have been provided with a sample of the soil for analysis. The sample is placed inside a specially designed container that permits radiation particles and rays to exit only in a straight-line path. Your laboratory contains all other necessary apparatus.

1. Describe a procedure for determining which types of radiation are being emitted by the soil sample. Include:

- a safety note to the rest of the clean-up crew describing the dangers associated with **one** of the three forms of radiation
- a description of the method you would use to identify alpha particles, beta particles, and gamma rays
- an explanation of how you would use your results to identify the types of radiation emitted by the soil

Scoring Guide for Holistic Questions

Major Concepts:	Magnetic field direction; Effect of an external magnetic field on moving charges; Experimental design
Score	**Criteria**
5 **Excellent**	• The student provides a complete solution that covers the full scope of the question. – The reader has no difficulty following the strategy or solution presented by the student. – Statements made in the response are supported explicitly but may contain minor errors or have minor omissions. *In the response, the student uses major physics generalizations such as balanced or unbalanced forces and conservation laws. The student applies knowledge from one area of physics to another.*
4 **Good**	• The student provides a solution to the significant parts of the question. – The reader may have some difficulty following the strategy or solution presented by the student. – Statements made in the response are supported implicitly and may contain errors. *In the response, the student uses major physics generalizations. The response is mostly complete, mostly correct, and contains some application of physics knowledge.*
3 **Satisfactory**	• The student provides a solution in which he/she has made significant progress toward answering the question. – The reader has difficulty following the strategy or solution presented by the student. – Statements made in the response may be open to interpretation and may lack support. *In the response, the student uses item-specific methods that reflect a knowledge-based approach, but the student does not apply them to the question.*
2 **Limited**	• The student provides a solution in which he/she has made some progress toward answering the question. – Statements made in the response lack support. *In the response, the student uses an item-specific method.*
1 **Poor**	• The student provides a solution that contains a relevant statement that begins to answer the question.
0 **Insufficient**	• The student provides a solution that is invalid for the question.
NR	No response is given.

Student Response 1

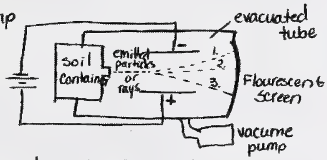
Saftey Note to Members of Crew

- please wear company lead suits to protect from radiated soil.
- always have glerger-muller counters on + ready
- radiation breaks down genetic material (DNA)
- keep soil away from gonads

MATERIALS

- soil container
- electrical conections
- vacume tube with parallel plates and flaurescent screen
- voltage source
- vacume pump

Apparatus



1. + 3. Deflected path of particle or ray.

NOTE: when soil container IS placed inside, there is an air tight seal.

Since alpha particles are positive, beta particles are negative, and gamma rays are neutral, we can use the above apparatus to determine the charge of the unknown particleor ray. Depending on the deflected path of the unknown radiation, we can confer that:

1. If the emitted radiation followed the deflection path #1 then it must have a positive charge since it is pulled toward the negative plate. Therefore, it would be a ALPHA PARTICLE
2. If the emitted radiation followed No deflection and followed path #2, then it must be neutral, since it is not effective by the electric field. Therefore, it would be GAMMA RAY
3. If the emitted radiation followed the deflection path #3 then it must have a negative charge since it is pulled toward the positive plate. Therefore, it would be a BETA PARTICLE

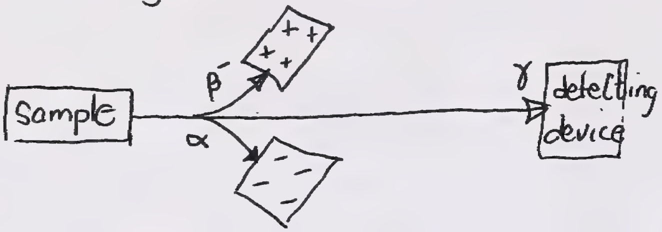
If there is more than one type of scattering in the tube, then there is more than one type of radiation in the soil.

Score – 5

Rationale

The student provides a complete solution that covers the full scope of the question. In doing so, the student provides a safety note, a procedure for determining which types of radiation are being emitted, and an explanation of how to interpret the results in order to identify the types of radiation. Statements made in the response are complete, well organized, and supported explicitly. The student uses an appropriate method that reflects an excellent understanding of the major concepts and indicates where these concepts apply to the solution. There is a weakness in the analysis of the observations in that the fluorescent screen would show impact points, not deflection paths. However, the use of physics principles to explain the paths overcomes this weakness, and the response receives full marks.

- The dangers of gamma rays are as follows:
  - destroy chemical bond in living cells
  - cause cancer
  - cause genetic mutation.



- Use electric field to bend alpha and beta particles. This can be done because both alpha and beta particles are charged particles: They will attract to one of the electric plate.
- But gamma ray has no charge. Thus it will go straight to the detecting deice

- To determine the types of radiation:
  - if a beam bends toward a positive plate, it is a beta particles because beta particle has negative charge
  - if a beam bends toward a negative plate, it is alpha particles because alpha particle has positive charge
  - if a beam goes straight through the electric field, it is a gamma rays becaus gamma rays have no charge and will not be affected by the electrc field.

Score – 4

Rationale

The student covers significant parts of the question. The safety n is clearly stated. There an explicit relationship between the diagram a the student's final bull The student uses an appropriate method tha mainly correct and complete. The student explicitly states the physics principle behin the analysis of the observations. The stud correctly relates the nature of the charge to radiation type and to th effect of the external electric field. The weakness in this respo is in the description of method of detecting th radiation. This part of response is incomplete and lacks support. The beta and alpha particle are not detected at all, the gamma radiation h a "detecting device."

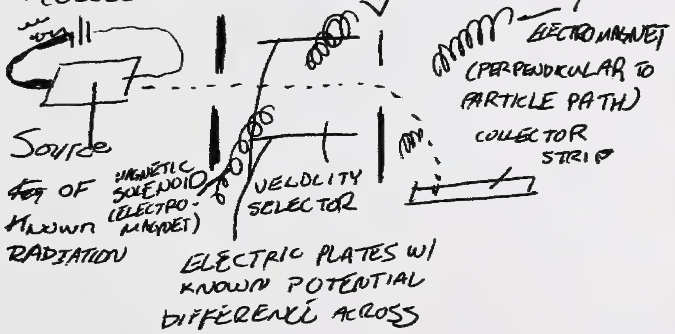
Student Response 3

SAFETY NOTE:

USE CAUTION AROUND THE CLEAN UP SITE AS HIGH PENITRATING GAMMA RAYS ARE PRESENT. THIS FORM OF EMR (ELECTROMAGNETIC RADIATION) IS PRODUCED IN ANY CASE OF RADIOACTIVE DECAY ALONG WITH ALPHA OR BETA PARTICLES. THEREFORE IT IS PRESENT HERE. ITS HIGH PENETRATING ABILITY IS DUE TO THE HIGH ENERGY OF ITS PHOTONS (HIGH FREQUENCY & SHORT WAVELENGTH) AND CAN ONLY BY STOPPED BY THICK SHEETS OF LEAD (OTHER MATERIALS CAN STOP GAMMA RAYS, BUT LEAD IS THE COMMONLY USED ONE). EXPOSURE TO GAMMA RADIATION CAN LEAD TO CANCER AS THE HIGH ENERGY PHOTONS CAN MUTATE LIVING CELLS.

IDENTIFYING ALPHA AND BETA PARTICLES:

WOULD SET UP AN APPARATUS CONSISTING OF THE RADIATION SOURCE, A VELOCITY SELECTOR (PERPENDICULAR MAGNETIC AND ELECTRIC FIELDS) AND ANOTHER MAGNETIC FIELD WITH A "COLLECTOR STRIP."


ELECTROMAGNET
(PERPENDICULAR TO PARTICLE PATH)
COLLECTOR STRIP
Source
OF KNOWN RADIATION
MAGNETIC SOLENOID (ELECTRO-MAGNET)
VELOCITY SELECTOR
ELECTRIC PLATES W/ KNOWN POTENTIAL DIFFERENCE ACROSS

Score – 3

Rationale

The student made progress toward answering the question. The safety note identifying the danger of cell mutation from gamma radiation is clear; however, the statement that "(electromagnetic radiation) is produced in any case of radioactive decay" presents a minor inaccuracy. The procedures for detecting the presence of alpha, beta, and gamma radiation are present and can be followed by the reader. However, the student demonstrates a limited understanding of the effect of the external fields on moving charged particles. The velocity selector and external magnetic field will produce a beam of charged particles that hit the collector strip. In order to use the same apparatus for oppositely charged types of radiation, changes would need to be made to the battery and to the second magnetic field, AT THE END OF THE APPARATUS WE KNOW THAT THE MAGNETIC FORCES THE CENTRIPEDAL FORCE, $F_M = F_C$, AS F_M IS ALL THAT IS ACTING ON THE UNKNOWN PARTICLES (GRAVITY IS WEAK IN COMPARISON).

$$F_M = F_C$$

$$q\cancel{v}B = \frac{mv^{\cancel{2}}}{r}$$

$$q = \frac{mv}{Br}$$

IF WE WISH TO FIND BETA PARTICLES (ELECRONS), WE IMPUT THE MASS AS THE MASS OF AN ELECTRON. IF $q = -1.60 \times 10^{-19}$C, THEN BETA RADIATION IS PRESENT.

FOR FINDING ALPHA PARTICLES (HELIUM NUCLEI), WE IMPUT THE MASS (m) AS THE MASS OF AN ALPHA PARTICLE. IF $q = 3.2 \times 10^{-19}$C, α^{+2} ARE PRESENT. "r" IS MEASURED FROM THE COLLECTOR STRIP "B" (MAGNETIC FIELD #2) IS KNOWN (CONTROLLED ELECROMAGNET)

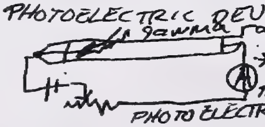
"v" CAN BE FOUND BECAUSE WE KNOW THAT $F_{ELECTRIC} = F_{MAGNETIC}$ IN THE VELOCITY SELECTOR.

$$F_C = F_M$$

$$\vec{E}\cancel{q} = \cancel{q}vB_\perp$$

$$v = \frac{\vec{E}}{B_\perp}$$

WE KNOW THAT GAMMA RAYS ARE PRESENT BECAUSE THEY ARE A BYPRODUCT OF ALL RADIO-ACTIVE DECAY. TO DETECT THEM WE CAN SET UP A PHOTOELECTRIC DEVICE



$\rightarrow W_{ork} + E_{k\,max} = qV_{stop}$ THE ENERGY OF THE PHOTO ELECTRON CAN BE FOUND,

AND $E_{PHOTOELECTRONS} = E_{PHOTONS(INCIDENT)}$, AND $E = hf$ $f = E/h$

NOW WE CAN SEE IF "f" MATCHES gamma

and fine-tuning would need to be done on the fields in the velocity selector. Without a method to measure the radius of the particle pa the procedure does not produce the measureme required for the analysi The student has not provided a method of identifying the radiatio types present in a samp this is a major omission The photoelectric effect apparatus is a poor choi for detecting gamma radiation. In addition, t description of the physi of the photoelectric effe is incorrect. The studen identification of the wo function is wrong, and t student didn't include t work function when usi Einstein's equation.

Student Response 4

a) WARNING! → this sample may contain highly radioactive substances including potentially harmful gamma rays. Gamma rays have been noted as being harmfully destructive and can cause the mutation of cells, noteably sex cells. Use of all protective gear is necessary.

To identify alpha or beta particles or gamma rays a decay could be performed on a well known element, with the result concluding the presence of alpha or beta particles, or gamma rays.

ex.) $^{266}_{109}Une \rightarrow {}^{262}_{107}Uns + {}^{4}_{2}He$ (prooves the presence of alpha particles)

Also, calculations could be made to determine the mass, charge, or wavelength of present particles/rays to further identify the type of radiation present.

Score – 1

Rationale
The student provides a solution that contains a relevant statement that begins to answer the question. The response contains a clear safety note relating gamma radiation to cell damage. The student, however, presents an incorrect strategy with little detail. In the response, the student uses a method that is inappropriate for the question. No method of interpreting results of the experiment to identify the type of radiation is given.

Student Response 5

- Caution this soil may contain harmful radiation, gamma rays. Please protect yourself when handling.
- I would use a set-up similar to Rutherford's gold foil experiment. Since radiation exits the container in a straight path, I could progect the radiation towards a devise to determine the frequency of the radiation. If the fequency is very high I found the presence of gamma rays. Alpha particles are nothing but helium. To determine their presence, I would simply do a diagnostic test for Helium Beta particles - take layers of skin and place any living organism. If the organism is not harmed then beta particles are present.

By finding what the soil gives off, I could possibly find out what the soil was exposed to to make it give off this radiation I know that whatever it was exposed to was extremly radioactive to give off gamma rays. I would take samples of normal soil and expose it to the most radioactive materials. By elimination, determine what happened to the original radioactive soil

Score – 0

Rationale

In this response, the student provides a solut that is invalid for the question. The student presents a safety note identifying gamma radiation as being harm but fails to describe the dangers associated with this form of radiation. student presents a meth for determining the typ of radiation that reflects little or no understandi of the major concepts. The student has attempt to present procedures, b the observations are inconsistent with the apparatus and the analy The Rutherford experiment will not measure gamma frequencies. The heliu diagnostic test would work, but the student d not explain it. The beta identification procedur invalid: it could suppor beta radiation, alpha radiation, or no emissio of radiation.

Sample Analytic Question, Solution, Scoring Guide, Students' Responses, and Rationales

Written-Response
Question 2, January 1998

A compact car with a mass of 1.0×10^3 kg is moving at 1.0×10^1 m/s north along a single-lane road. At the same time, a full-size car with a mass of 2.0×10^3 kg is moving at 8.0 m/s south along the same road. The two cars collide head-on. Immediately after the collision, the compact car has a velocity of 4.0 m/s south. The interaction lasted 8.0×10^{-2} s.

- Determine the speed and direction of the full-size car immediately after the collision.
- Show that the collision was **not** elastic.
- Determine the magnitudes and the directions of the average forces of impact on the compact car and on the full-size car.

Clearly communicate your understanding of the physics principles that you are using to solve this question. You may communicate this understanding mathematically, graphically, and/or with written statements.

Sample Solution

- Determine the speed and direction of the full-size car immediately after the collision.

  Momentum before collision must equal momentum after collision.

  $\sum \vec{p}_{\text{i}} = \sum \vec{p}_{\text{f}}$: one dimensional problem N +
  S −

  $$m_1\vec{v}_{1\text{i}} + m_2\vec{v}_{2\text{i}} = m_1\vec{v}_{1\text{f}} + m_2\vec{v}_{2\text{f}}$$

  $$\vec{v}_{2\text{f}} = \frac{m_1\vec{v}_{1\text{i}} + m_2\vec{v}_{2\text{i}} - m_1\vec{v}_{1\text{f}}}{m_2}$$

  $$\vec{v}_{2\text{f}} = \frac{(1.0 \times 10^3\,\text{kg})(1.0 \times 10^1\,\text{m/s}) + (2.0 \times 10^3\,\text{kg})(-8.0\text{m/s}) - (1.0 \times 10^3\,\text{kg})(-4.0\text{m/s})}{2.0 \times 10^3\,\text{kg}}$$

  $$\vec{v}_{2\text{f}} = -1.0\ \text{m/s}$$

  The velocity of the full-size car is 1.0 m/s south.

- Show that the collision was **not** elastic.

  If the collision is elastic, then kinetic energy is conserved.

  $\sum E_{\text{ki}} = \sum E_{\text{kf}}$ if the collision is elastic.

  $$\sum E_{\text{ki}} = \frac{1}{2}m_1 v_{1\text{i}}^2 + \frac{1}{2}m_2 v_{2\text{i}}^2$$

$$\sum E_{\text{ki}} = \frac{1}{2}(1.0 \times 10^3\ \text{kg})(1.0 \times 10^1\ \text{m/s})^2 + \frac{1}{2}(2.0 \times 10^3\ \text{kg})(8.0\ \text{m/s})^2$$

$$\sum E_{\text{ki}} = 1.14 \times 10^5\ \text{J}$$

$$\sum E_{\text{ki}} = 1.1 \times 10^5\ \text{J}$$

$$\sum E_{\text{kf}} = \frac{1}{2} m_1 v_{1\text{f}}^{\ 2} + \frac{1}{2} m_2 v_{2\text{f}}^{\ 2}$$

$$\sum E_{\text{kf}} = \frac{1}{2}(1.0 \times 10^3\ \text{kg})(4.0\ \text{m/s})^2 + \frac{1}{2}(2.0 \times 10^3\ \text{kg})(1.0\ \text{m/s})^2$$

$$\sum E_{\text{kf}} = 9.0 \times 10^3\ \text{J}$$

Since $\sum E_{\text{ki}} > \sum E_{\text{kf}}$, the collision was inelastic.

- Determine the magnitudes and the directions of the average forces of impact on the compact car and on the full-size car.

The force on the compact car is given by

$$\vec{F}\Delta t = m\Delta\vec{v}$$

$$\begin{aligned} \vec{F} &= \frac{m\Delta\vec{v}}{\Delta t} \\ &= \frac{m(\vec{v}_{1\text{f}} - \vec{v}_{1\text{i}})}{\Delta t} \\ &= \frac{(1.0 \times 10^3\text{kg})(-4.0\ \text{m/s} - 1.0 \times 10^1\ \text{m/s})}{8.0 \times 10^{-2}\text{s}} \\ F &= -1.8 \times 10^5\ \text{N} \end{aligned}$$

The force on the full-size car is given by

$$\vec{F} = \frac{(2.0 \times 10^3\text{kg})(-1.0\ \text{m/s} - (-8.0\ \text{m/s}))}{8.0 \times 10^{-2}\text{s}}$$

$$F = 1.8 \times 10^5\ \text{N}$$

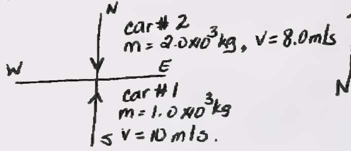
The magnitude of the force on the compact car is 1.8×10^5 N, and the direction is south. Since the forces on the compact car and the full-size car are an action–reaction pair, the magnitude of the force on the full-size car is 1.8×10^5 N and its direction is north.

Scoring Guide for Anaholistic Questions

Major Concepts: Graphing data; Calculation of slope and identifying physics quantity; Balanced Forces; Data Analysis	
Score	**Criteria**
5	In the response, the student • uses an appropriate method that reflects an **excellent understanding** of all major concepts • provides a complete description of the method used and shows a complete solution for the problem • states formulas explicitly • may make a minor error, omission, or inconsistency; however, this does not hinder the understanding of the physics content • draws diagrams that are appropriate, correct, and complete • may have an error in significant digits or rounding
4	In the response, the student • uses an appropriate method that reflects a **good understanding** of all major concepts **or** that reflects an **excellent understanding** of three of the major concepts • provides explanations that are correct and detailed • states most formulas explicitly and applies them correctly • makes minor errors, omissions, or inconsistencies in calculations and/or substitutions; however, these do not hinder the understanding of the physics content • draws most diagrams appropriately, correctly, and completely • may have errors in units, significant digits, rounding, or graphing
3	In the response, the student • uses an appropriate method that reflects a **basic understanding** of all four of the major concepts **or** that reflects a **good understanding** of three of the major concepts • uses an appropriate method that reflects an **excellent understanding** of two of the major concepts **and** that reflects a **basic understanding** of one of the two remaining concepts • uses formulas and/or diagrams that may be implicit, and these are applied correctly; however, errors in calculations and/or substitutions that hinder the understanding of the physics content are present • provides explanations that are correct but lack detail • has a major omission or inconsistency
2	In the response, the student • uses an appropriate method that reflects a **basic understanding** of three of the four major concepts **or** that reflects a good understanding of two of the major concepts • gives formulas and/or diagrams that are implicitly correct; however, they are not applied to determine the final solution **or** errors in the application of equations are present, but the answer is consistent with calculated results
1	In the response, the student • attempts at least two of the major concepts **or** uses **an appropriate method** that reflects a good understanding of one of the major concepts • makes errors in the formulas, diagrams, and/or explanations, and the answer is not consistent with calculated results
0	In the response, the student • identifies an area of physics that does not apply to the major concepts • uses inappropriate formulas, diagrams, and/or explanations
NR	No response is given.

Student Response 1

Before the Collision



i = initial, f = final.

* Conservation of momentum states that momentum before collision must equal momentum after collision.

Car#1 car#2 car#1 car#2

$m_i v_i + m_i v_i = m_f v_f + m_f v_f$

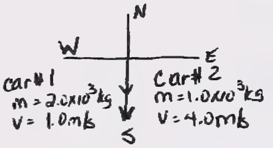
$(1.0\times10^3 kg)(-10\frac{m}{s}) + (2.0\times10^3 kg)(8.0\frac{m}{s}) = (1.0\times10^3 kg)(4.0\frac{m}{s}) + (2.0\times10^3 kg)v_f$

$-1.0\times10^4 \, kgm/s + 1.6\times10^4 \, kgm/s = 4.0\times10^3 \, kgm/s + 2.0\times10^3 \, kg\cdot v_f$

$6.0\times10^3 \, kgm/s = 4.0\times10^3 \, kgm/s + 2.0\times10^3 \, kg\cdot v_f$

$2.0\times10^3 \, kg\cdot\frac{m}{s} = (2.0\times10^3 kg)(v_f)$

$v_f = 1.0 \, m/s$



Car#2 was moving at 1.0 m/s South after.

Elastic Collision means that Kinetic Energy before = Energy After

Car#1 car# 2 car#1 car#2

$\frac{1}{2}m_1v_1^2 + \frac{1}{2}m_1^2 = \frac{1}{2}mv_f^2 + \frac{1}{2}mv_f^2$

$\frac{1}{2}(1.0\times10^3)(-10)^2 + \frac{1}{2}(2.0\times10^3)(8.0)^2 = \frac{1}{2}(1.0\times10^3)(4.0)^2 + \frac{1}{2}(2.0\times10^3)(1.0)^2$

$-5.0\times10^4 J + 6.4\times10^4 J = 8.0\times10^3 J + 1.0\times10^3 J$

before after

$1.4\times10^4 J = 9.0\times10^3 J$

$5.0\times10^3 J$ of Energy were lost during collision

∴ inelastic collision because energy before did not equal energy after.

Avg Force of Impact

$F\Delta t = m\Delta v$

Car#1 $F(8.0\times10^{-2} s) = (1.0\times10^3 kg)(-10\frac{m}{s} - 4\frac{m}{s})$

$F = 1.75\times10^5 N$ was the avg force exerted on the car during collision in a north direction

Car#2 $F\Delta t = m\Delta v$

$F(8.0\times10^{-2} s) = (2.0\times10^3 kg)(8.0\frac{m}{s} - 1.0\frac{m}{s})$

$F = 1.75\times10^5 N$ was the avg force exerted on the car in a south direction during collision.

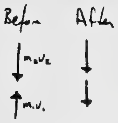
Score – 4

Rationale

By providing formulas, diagrams, and statements, the student reveals an excellent understanding of physics concepts and communication skills. The treatment of vectors in the response is **excellent**. The student establishes a sign convention (e.g., south is positive) and uses it consistently. The explanation of the conservation of momentum concept is also **excellent**. Formulas, substitutions, and a statement of outcome are all present. The response shows a **good** understanding of inelastic collisions, but it contains an arithmetic error (negative energy) and a mathematical error (equating unequal values). These do not hinder the understanding of the physics concepts. The student shows a **good** understanding of forces by providing formulas and statements. However, the force calculations contain an error in the reversed substitution into Δ*v*. This results in both forces being identical in size and direction, which creates a minor error.

Student Response 2

Using the conservation of momentum theory and the formula, $\overset{(before)}{m_1v_1 + m_2v_2} = \overset{(after)}{m_1v_1 + m_2v_2}$ I can solve for the speed of the car after the collision. Using a vector diagram and vector addition I can solve for direction.



Before

$m_1 = 1000$ kg
$v_1 = 10$ m/s N
$m_2 = 2000$ kg
$v_2 = 8$ m/s S

After

$m_1 = 1000$ kg
$v_1 = 4$ m/s S
$m_2 = 2000$ kg
$v_2 : ?$

$$\overset{Before}{m_1v_1 + m_2v_2} = \overset{After}{m_1v_1 + m_2v_2}$$

$$1000\text{kg} \times 10\text{ m/s} + 2000\text{kg} \times -8\text{ m/s} = 1000\text{kg} \times -4\text{ m/s} + 2000\text{kg} \times v_2$$

$$-6000\text{ kgm/s} = -4000\text{ kgm/s} + 2000\text{kg} \times v_2$$
$$+4000\text{ kgm/s} \qquad +4000\text{ kgm/s}$$

$$\frac{-2000\text{ kgm/s} = 2000\text{ kgm/s}}{2000\text{ kgm/s}} \times v_2 \qquad \boxed{\therefore v_2 = -1\text{ m/s}}$$

The full size car is travelling 1.0 m/s South.

Using conservation of energy I can show the collision was not elastic

Before

$$E_k = \frac{m_1v_1^2}{2} + \frac{m_2v_2^2}{2}$$
$$= \frac{1000\text{kg} \times 10^2\text{m/s}}{2} + \frac{2000\text{kg} \times -8^2\text{m/s}}{2}$$
$$= 1.14 \times 10^5\text{ J}$$

After

$$E_k = \frac{m_1v_1^2}{2} + \frac{m_2v_2^2}{2}$$
$$= \frac{1000\text{kg} \times 4^2\text{m/s}}{2} + \frac{2000\text{kg} \times 1^2\text{m/s}}{2}$$
$$= 9.0 \times 10^3\text{ J}.$$

The energy before the collision is greater than after, so the collision is not elastic.

Using the impulse formula I can find the force acting on each car.

compact $F = \frac{m\Delta v}{t} = \frac{1000\text{kg} \times (10\text{ m/s})}{0.08\text{ s}}$

$F = 1.25 \times 10^5$ N North

full size $F = \frac{m\Delta v}{t} = \frac{2000\text{kg} \times (8\text{ m/s})}{0.08\text{ s}}$

$F = 2.0 \times 10^5$ N South.

The magnitude and directions of the impact forces of each car are: compact car → 1.3×10^5 N North Full size → 2.0×10^5 N South.

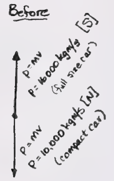
Score – 3

Rationale

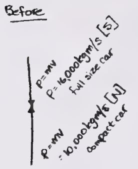
The response reveals an **excellent** understanding of conservation of momentum: it provides a supporting statement, formulas, correct substitutions, and a answer consistent with those substitutions. An **excellent** understanding of inelastic collisions is shown in the statement, formulas, and comparison of kinetic energy before and after the collision. The student shows a **good** understanding of vectors by using directions correctly in the momentum calculations; however, this understanding is not evident in the force calculations. The understanding of the major concept of forces is **basic**, as shown in the student's use of the incorrect substitution of v_i for Δv. This incorrect substitution shows an incomplete understanding of physics concepts.

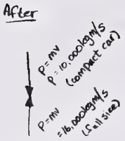
Student Response 3

Vector diagram



Vector Addition Diagram





Givens

① $m_1 = 1.0 \times 10^3 \text{ kg}$
$\vec{v}_1 = 1.0 \times 10^1 \text{ m/s}$
$m_2 = 2.0 \times 10^3 \text{ kg}$
$\vec{v}_2 = 8.0 \text{ m/s}$
$* \vec{v}_1{}' = 4.0 \text{ m/s}$

Unknowns

$* \vec{v}_2{}' = ?$

③ formulae

$$\vec{p}_1 + \vec{p}_2 = {}^*\vec{p}_1{}' + {}^*\vec{p}_2{}'$$

$$m_1\vec{v}_1 + m_2\vec{v}_2 = m_1\vec{v}_1{}' + m_2\vec{v}_2{}'$$

④ Solved formula

$$\frac{m_1\vec{v}_1 + m_2\vec{v}_2 - m_1\vec{v}_1{}'}{m_2} = \vec{v}_2{}'$$

⑤ $$\frac{m_1\vec{v}_1 + m_2\vec{v}_2 - m_1\vec{v}_1{}'}{m_2} = \vec{v}_2{}'$$

$$\vec{v}_2{}' = \frac{(1.0\times10^3 \text{kg})(1.0\times10^1 \text{m/s}) + (2.0\times10^3 \text{kg})(8.0 \text{m/s}) - (1.0\times10^3 \text{kg})(4.0 \text{m/s})}{2.0\times10^3 \text{kg}}$$

$v_2{}' = 11.0 \text{ m/s [N]}$

$* v_1{}'$ = velocity after collision (compact car)
$* v_2{}'$ = velocity after collision (full size car)
$* p_1$ = total momentum before collision
$* p_2$ = total momentum after collision

According to the laws of conservation of energy and momentum total momentum before the collision equals total momentum after the collision. There for given the velocities before and given the masses of the objects one can find the velocity of the object II using the formula $\vec{p}_1 + \vec{p}_2 = \vec{p}_1{}' + \vec{p}_2{}'$

- The collision was not elastic because in an elastic collision both energy and momentum are conserved but in this collision only momentum was conserved and the energy was lost due to heat, sound etc.

- Average Forces

on compact car

$$F_{avg} = E_p + E_k$$
$$= mgh + \frac{mv^2}{2}$$

full size car

$$F_{avg} = E_p + E_k$$
$$= mgh + \frac{mv^2}{2}$$

Score – 2

Rationale

The student **attempts** vector analysis by providing diagrams. However, no attempt is made to incorporate the meaning of the vector directions in the calculations. Therefore, the response does not reflect a **basic** understanding. The student demonstrates an **excellent** understanding of conservation of momentum by providing formulas, substitutions, a consistent solution, and a statement of the conservation law. The student shows a **good** understanding of inelastic collisions by indicating that energy is not conserved when they occur and by identifying where the energy is lost in this situation. The student attempts to address forces but does not show a **basic** understanding as energies and forces are equated.

MAY 29 2004